

# MAss Spectrometer for Planetary EXploration (MASPEX)

J. Hunter Waite, Tim Brockwell, Paul Wilson, Keith  
Pickens, John Roberts, Greg Miller  
Southwest Research Institute



# TOF Concept

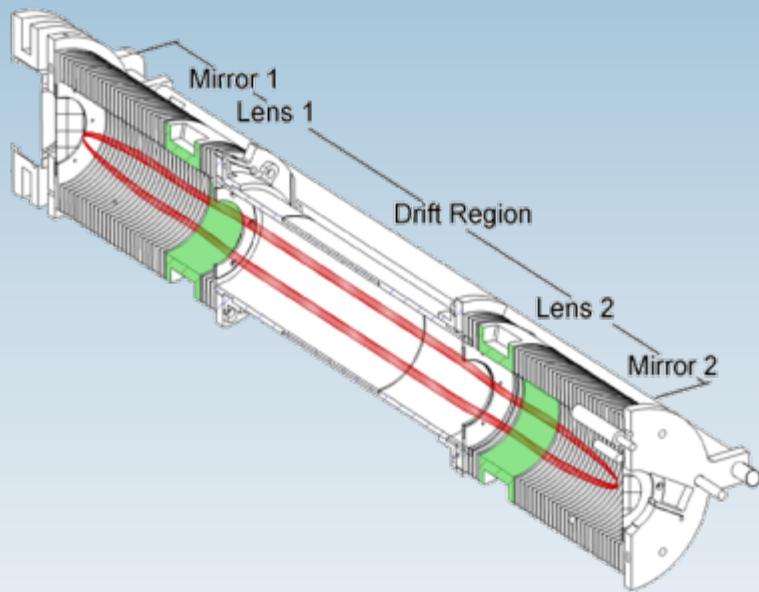
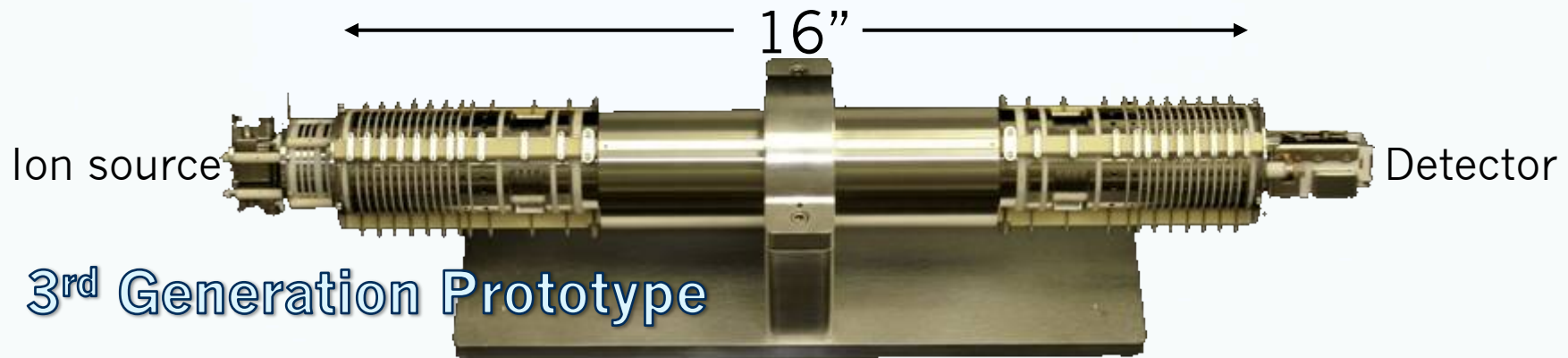
- A packet of ions is accelerated to a defined kinetic energy and the time required to move through a fixed distance is measured
- As  $KE = mv^2/2$  then lighter ions travel faster than heavier ones → mass separation
- The greater the distance between source and detector the smaller the mass difference that can be seen (resolution)



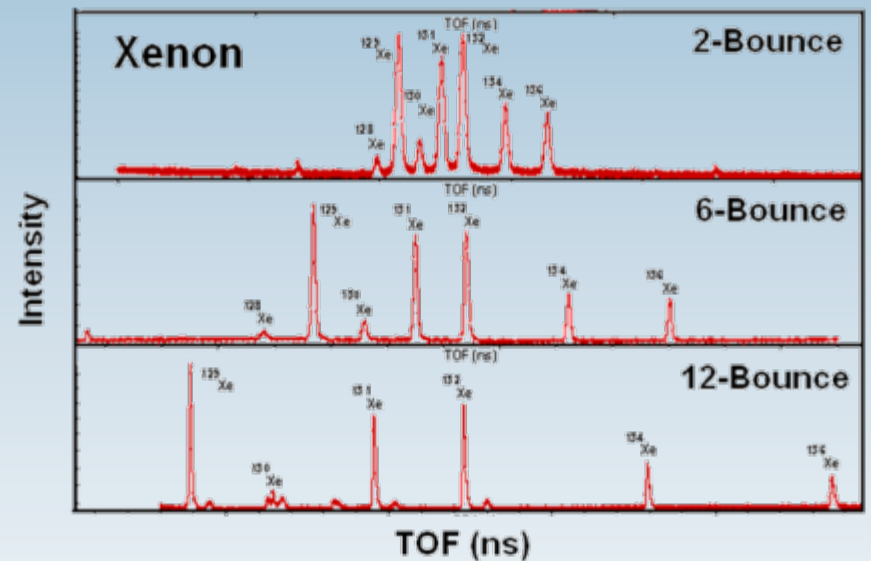
# MASPEX performance comparison

		MASPEX	Cassini INMS	
Storage source increases duty cycle to ~100%, provides ~200,000 ions per extraction	Sensitivity (N <sub>2</sub> )	0.02	0.0006	counts/s per particle/cm <sup>3</sup>
Multi-bounce geometry enables variable path length increasing resolution	Resolution m/ Δ m	12,300	~200	FWHM
Maximum mass limited by flight time not by field strength or frequency	Mass range	1-1000	1-8, 12-99	u
2000 source extractions per second, each producing a spectrum, provides increased spatial resolution and sensitivity	Single spectrum acquisition time	0.5	34	ms
Dual stage detector provides wide dynamic range	Dynamic range	10 <sup>9</sup>	10 <sup>8</sup>	

# Resolution: Multi-Bounce Time-of-Flight

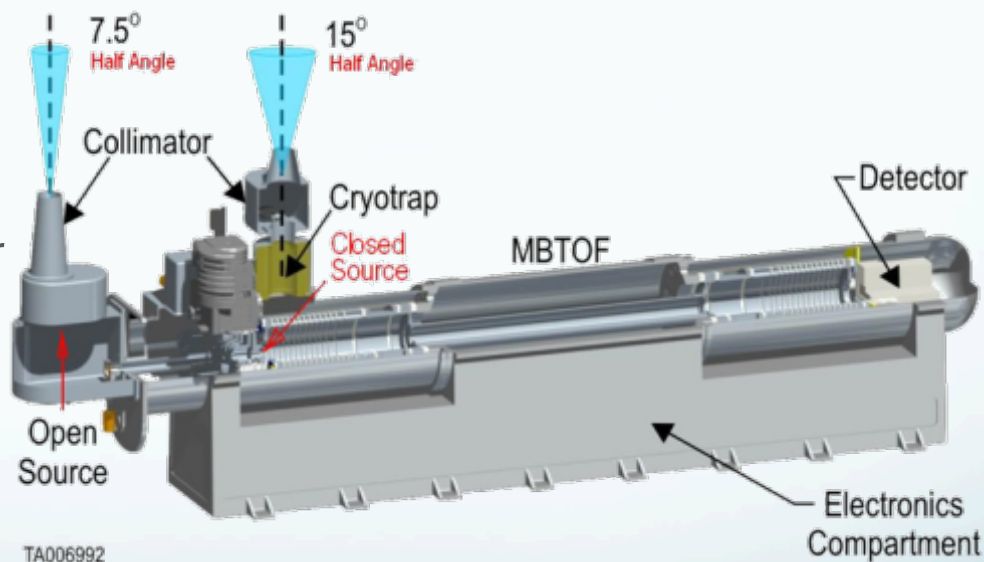


Mass Resolution = 10,800 in 12 bounces



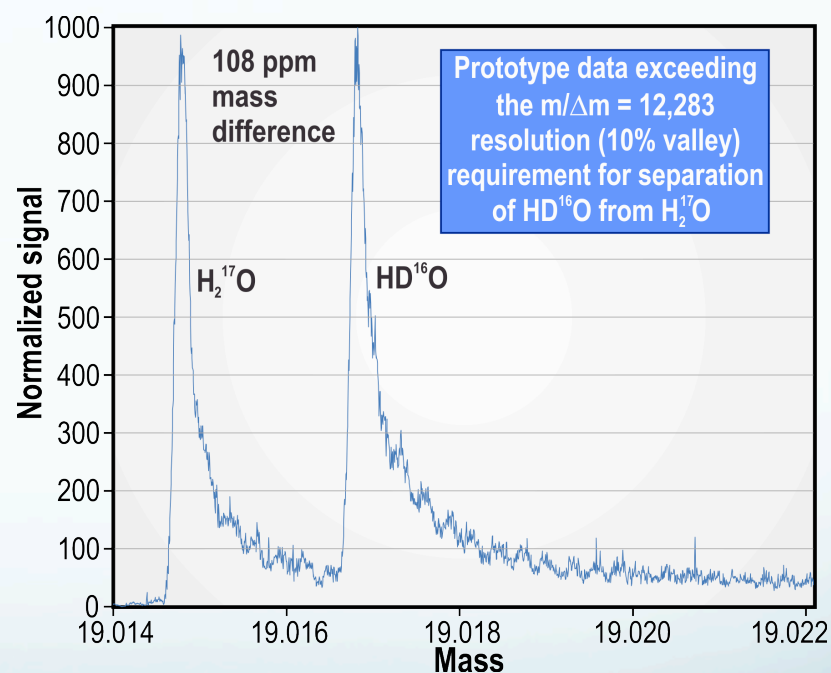
# MASPEX Performance

- Extended mass range for heavy organic molecules ( $>1000$  u)
- Enhanced mass resolution for critical isotopes ( $>10,000$  m/  $\Delta$  m)
- Enhanced dynamic range for high S/N ( $10^9$  in a 1s period)
- Improved sensitivity for rare noble gases ( $>1$  ppt with cryotrap)
- High throughput (2000 spectra/s)



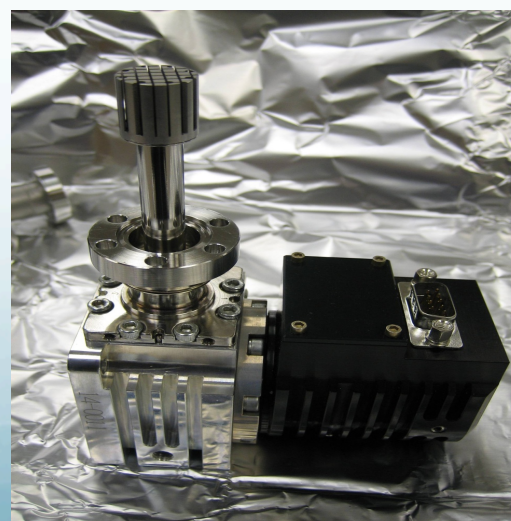
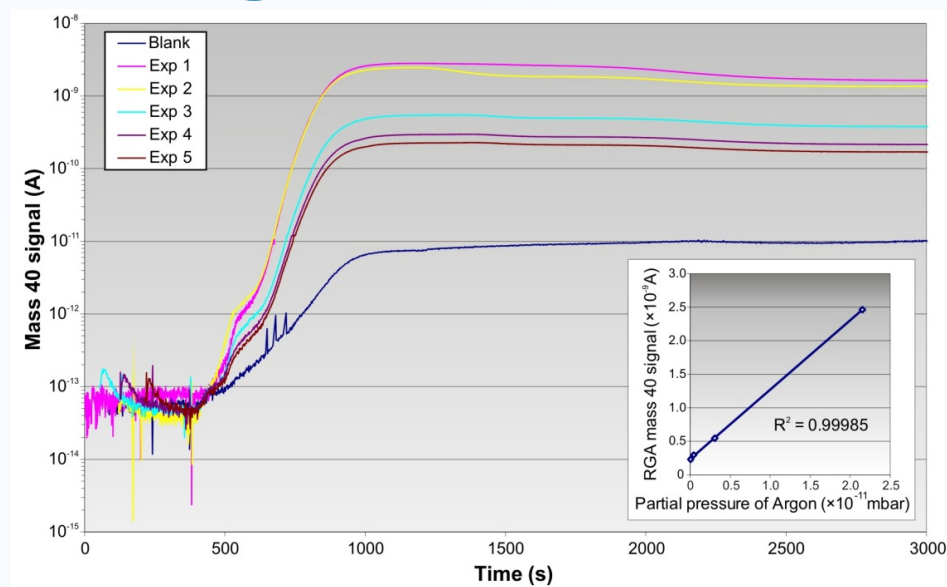
# Isotopic determination in complex volatile mixtures

- High mass resolution mass spectrometry is essential for H, C, N, and O isotope determination in complex mixtures containing water, ammonia, methane, and organic volatiles.
- Shown here is the determination of the H/D ratio in water requiring a resolution of 12,300, which takes 30 bounces on the MBTOF.



# High Sensitivity: Cryo-trapping

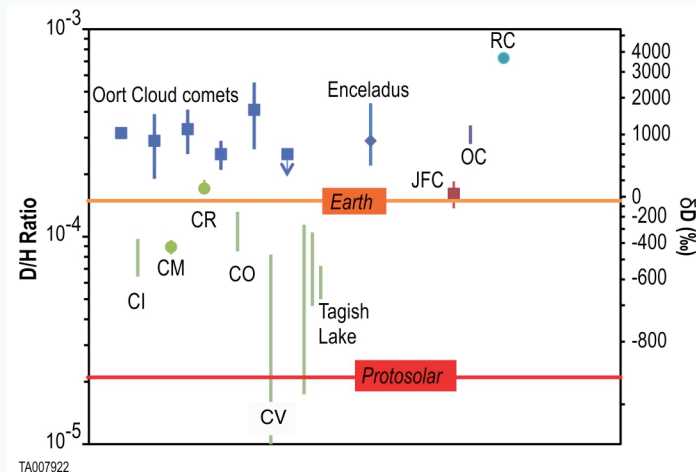
- Argon over 5 sample sizes and a blank.
  - The sample is held on the adsorber to ~450 seconds
  - During this period the ion pump is opened and a dip in the line would indicate that some of the sample remains unadsorbed
  - The noisy trace seen here is because the RGA is at the limit of its sensitivity.
  - The ion pump is then closed and the adsorber allowed to warm to room temperature, during which period the trapped sample is evolved.
  - After deducting the blank contribution the samples fit the calibration curve with an  $R^2$  value of 0.99985 and indicate that the adsorber is quantitative.



# Versatility

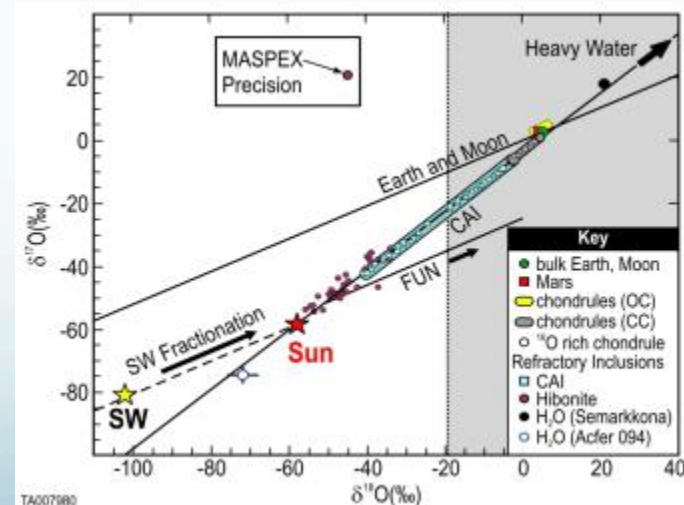
- Open source
  - Ions
  - Reactive neutrals
- Closed source
  - Ambient gas
  - Cryotrapped gas
    - Increased sensitivity
    - Purification (NEG)
- MBTOF
  - Extraction rate
    - power / integration time
  - Resolution
    - selectivity / mass range
  - Integration time
    - data rate / dynamic signals

# Formation: Hydrogen and oxygen isotopes in water



- D/H in the solar system taken from Alexander et al.[2012].
- Tagish Lake is best chondritic match to P and D type asteroids that formed the Galilean and Saturnian satellites and also likely represents the rocky fraction of cometary materials.

- Oxygen isotopes in the solar system from McKeegan et al. [2009].
- Measurements of oxygen isotopes of water are virtually non-existent in the outer solar system – the gray area delineates out our present ambiguity.



# Astrobiological Studies

**MARS ANALYTICAL  
CHEMISTRY EXPERIMENT  
(MACE)**

PI: J. Hunter Waite  
University of Michigan

**PICASSO:**  
PYROLYSIS INLET  
CHROMATOGRAPHIC  
ANALYTICAL SPECTROMETER  
FOR SURFACE ORGANICS

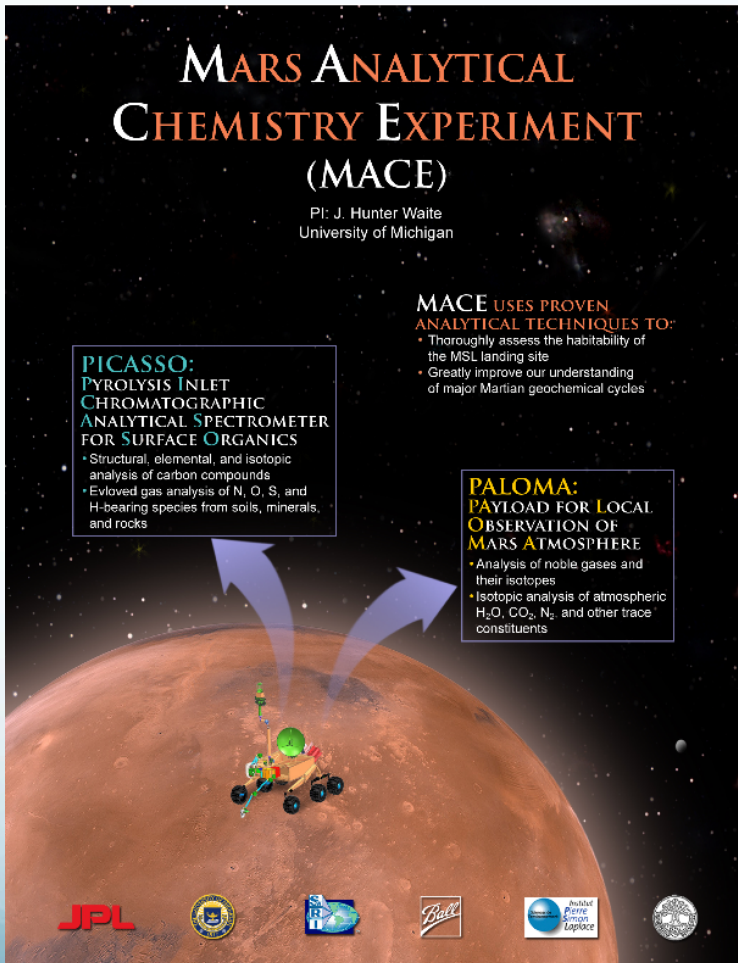
- Structural, elemental, and isotopic analysis of carbon compounds
- Evolved gas analysis of N, O, S, and H-bearing species from soils, minerals, and rocks

**MACE USES PROVEN ANALYTICAL TECHNIQUES TO:**






- Thoroughly assess the habitability of the MSL landing site
- Greatly improve our understanding of major Martian geochemical cycles

**PALOMA:**  
PAYLOAD FOR LOCAL  
OBSERVATION OF  
MARS ATMOSPHERE

- Analysis of noble gases and their isotopes
- Isotopic analysis of atmospheric H<sub>2</sub>O, CO<sub>2</sub>, N<sub>2</sub>, and other trace constituents

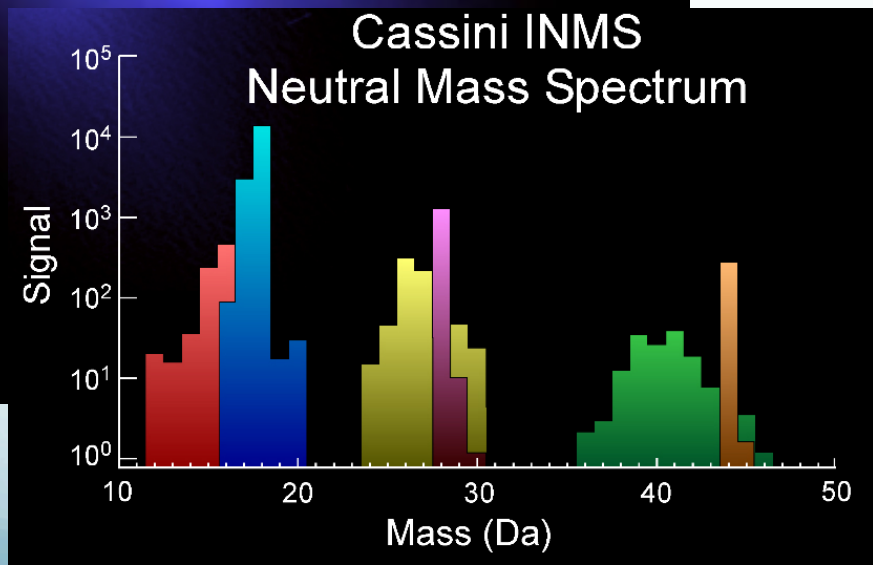


JPL

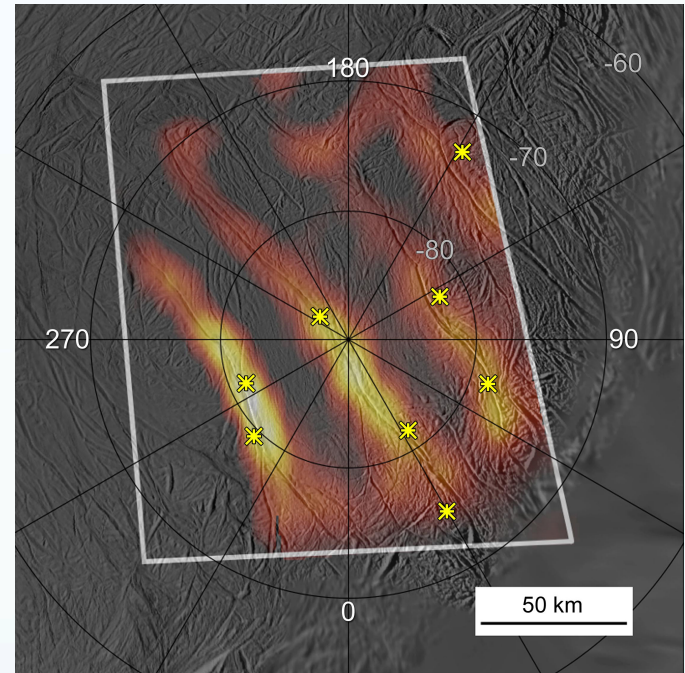


# Studies of Interior Processes

## Enceladus Cryo-Geyser

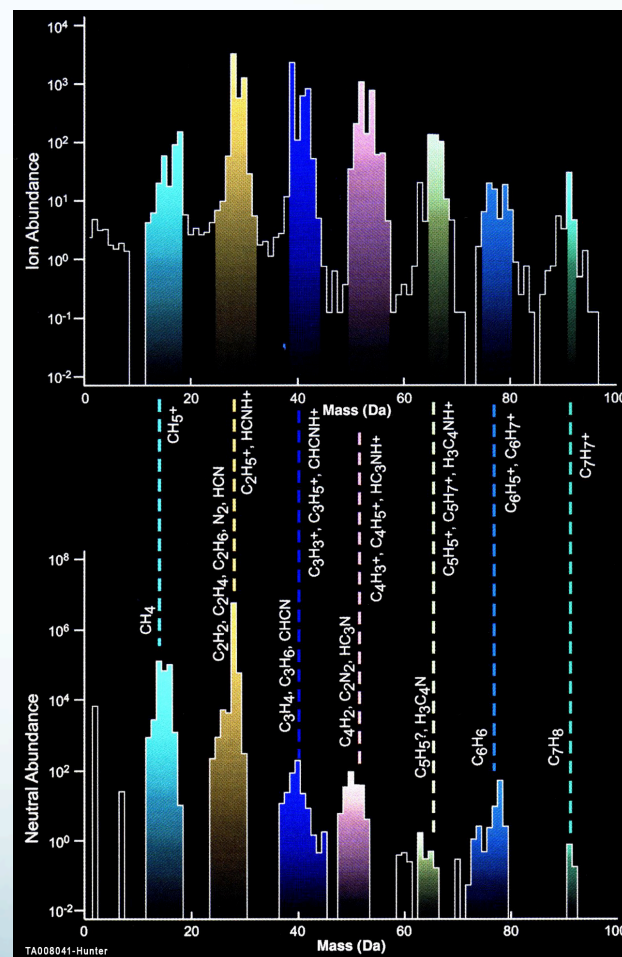
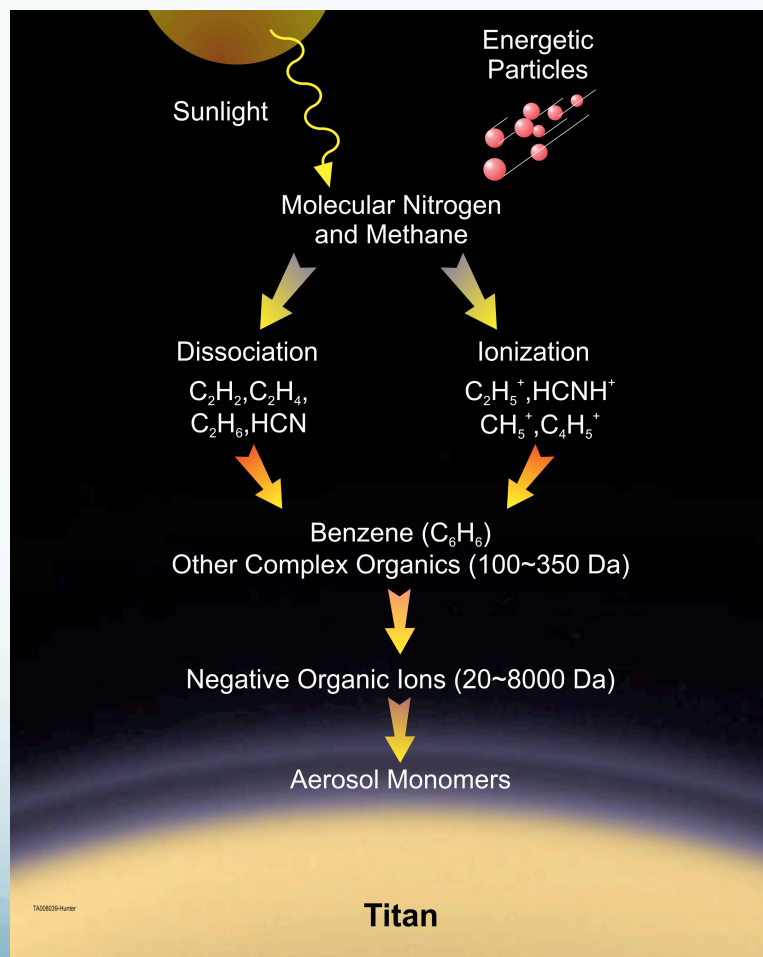


Composition like a comet?



Tidal heating of the icy interior

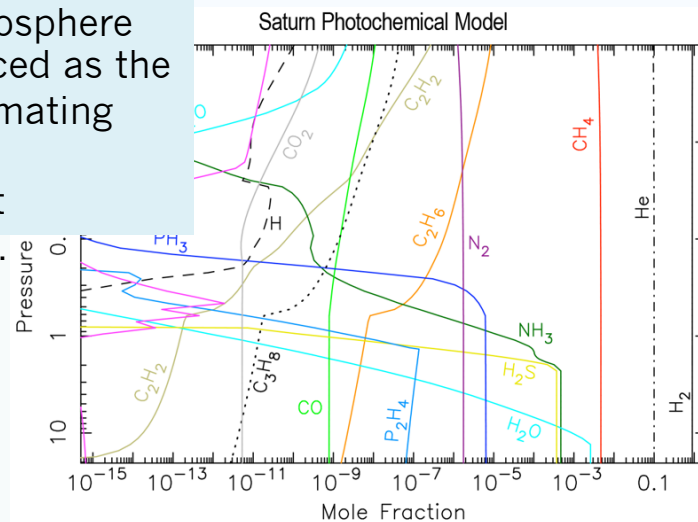
# Atmospheric Chemistry and Structure



After Waite et al, Science, **316** p. 870 (2007)

# Meeting the Science Requirements

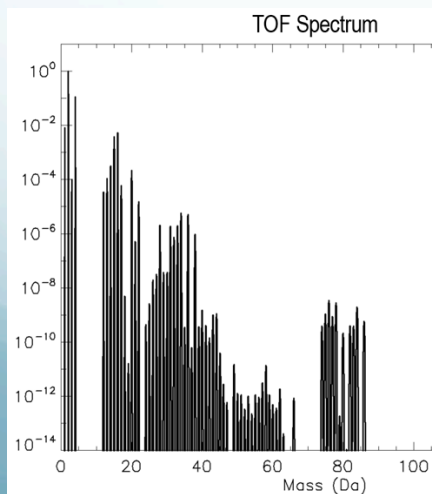
**STEP 1:** Atmosphere model produced as the basis for estimating the MASPEX measurement requirements.



Results for the Measurement of Ambient Gas at 0.5 bar

Molecule	Specific isotope	Exact mass RMM g/mol	Principal isotope	Molecular abundance	Mixing fraction	Min required acquisition time sec	Target precision	Minimum bounces required
H <sub>2</sub>	<sup>1</sup> H <sub>2</sub>	2.0	P	0.895	0.895	<0.1	5%	0
H <sub>2</sub>	<sup>1</sup> H <sup>2</sup> H	3.0	2H	0.895	3.58E-5	<0.1	5%	4
He	<sup>3</sup> He	3.0	3He	0.1	4.64E-5	<0.1	10%	4
He	<sup>4</sup> He	4.0	P	0.1	0.1	<0.1	5%	0
CH <sub>4</sub>	<sup>12</sup> C <sup>1</sup> H <sub>4</sub>	16.0	P	0.005	0.005	<0.1	1%	0
CH <sub>4</sub>	<sup>13</sup> C <sup>1</sup> H <sub>4</sub>	17.0	13C	0.005	5.25E-5	1.7	1%	0
CH <sub>4</sub>	<sup>12</sup> C <sup>1</sup> H <sub>3</sub> <sup>2</sup> H	17.0	2H	0.005	3.72E-7	9.7	5%	21
N <sub>2</sub>	<sup>14</sup> N <sub>2</sub>	28.0	P	1.75E-6	1.74E-6	0.3	10%	3
Ne	<sup>20</sup> Ne	20.0	P	2.06E-4	1.92E-4	<0.1	10%	0
Ne	<sup>22</sup> Ne	22.0	22Ne	2.06E-4	1.39E-5	0.2	10%	0
NH <sub>3</sub>	<sup>14</sup> N <sup>1</sup> H <sub>3</sub>	17.0	P	1.39E-7	1.39E-7	7.7	10%	8
Ar	<sup>36</sup> Ar	36.0	P	5.37E-6	1.81E-8	21.1	10%	0
Ar	<sup>38</sup> Ar	38.0	38Ar	5.37E-6	3.41E-9	111.7	10%	0
C <sub>2</sub> H <sub>6</sub>	<sup>12</sup> C <sup>1</sup> H <sub>6</sub>	30.0	P	3.34E-8	3.27E-8	2219.5	1%	3
C <sub>2</sub> H <sub>6</sub>	<sup>12</sup> C <sup>13</sup> C <sup>1</sup> H <sub>6</sub>	31.1	13C	3.34E-8	7.38E-10	98205.	1%	16
Kr	<sup>80</sup> Kr	79.9	80Kr	3.04E-9	6.89E-11	13948.3	10%	3
Kr	<sup>82</sup> Kr	81.9	82Kr	3.04E-9	3.51E-10	2734.5	10%	0
Kr	<sup>83</sup> Kr	82.9	83Kr	3.04E-9	3.49E-10	2748.1	10%	0
Kr	<sup>84</sup> Kr	83.9						
Kr	<sup>86</sup> Kr	85.9						
Xe	<sup>129</sup> Xe	127.9						
Xe	<sup>130</sup> Xe	128.9						
Xe	<sup>131</sup> Xe	129.9						
Xe	<sup>132</sup> Xe	130.9						
Xe	<sup>133</sup> Xe	131.9						
Xe	<sup>134</sup> Xe	133.9						
Xe	<sup>136</sup> Xe	135.9						

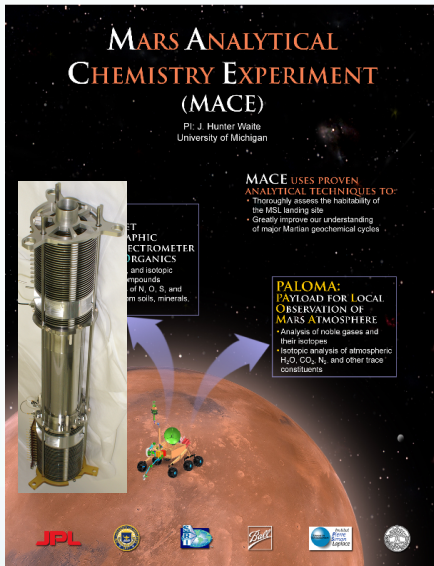
**STEP 3:** Spreadsheet program developed to determine mass resolution and measurement time needed to satisfy the RFI requirements and thus generate a realistic operational scenario.



**STEP 2:** Simulated MASPEX spectrum generated using lab line shapes from our mass spectrometer combined with NIST fragmentation and ionization data, and solar isotopic abundance information.

# Summary

- MASPEX has a long history of development from internal and, more recently, external sources



- NASA's funding of the PriME Technology Development and ICEE program demonstrate NASA's confidence to the development of MASPEX